Chapter 8
Example Case 2

In this example, we will change the rigid-blade, rigid shaft model from the previous example to a flexible-blade, flexible shaft (torsion-only) model. This will demonstrate the required steps for removing and replacing some large sections of the model, along with how to modify other parts inside the WT interface.

8.1 Outline

NOTE: To work through this example, you should switch into the *nrel/examples/case_2* directory before starting ADAMS/View. As for the first example, assuming you have set up the environment variables and *aview.pth* file correctly, you can then start View and load the ADAMS/WT overlay by reading in the command file *wt_main.cmd*. (See Appendix J for more information on setting up WT.) At this point you should be ready to begin case_2.

1. Delete the default *hawt* model.
2. Load the *case_1* model from a command file.
3. Change the model name to *case_2*.
4. Remove the rotor blades.
5. Create a new, flexible blade #1 and relocate it to one end of hub.
6. Create a new, flexible blade #2 and relocate it to other end of hub.
7. Add the tip weights to each blade.
8. Add AeroDyn aerodynamics to each blade.
9. Replace low-speed shaft weld with a torsional spring.
10. Add bearing to *lss2* part of shaft.
11. Add a REQUEST to monitor shaft torsional response.
12. Fix SENSOR (only if you are running ADAMS 8.1)
12. Do the analysis (using same executable and aero as for *case_1*).
13. Look at the results.

NOTE AGAIN: In order to avoid losing your work, we recommend that you save the ADAMS/View session to a binary file after each section in the example is completed. This can be most easily done through the FILE SAVE menu, or alternately from the command line in A/View by typing:

file binary write file=case_2 (or just *fil bin wri fil=case_2*)

8.2 Startup

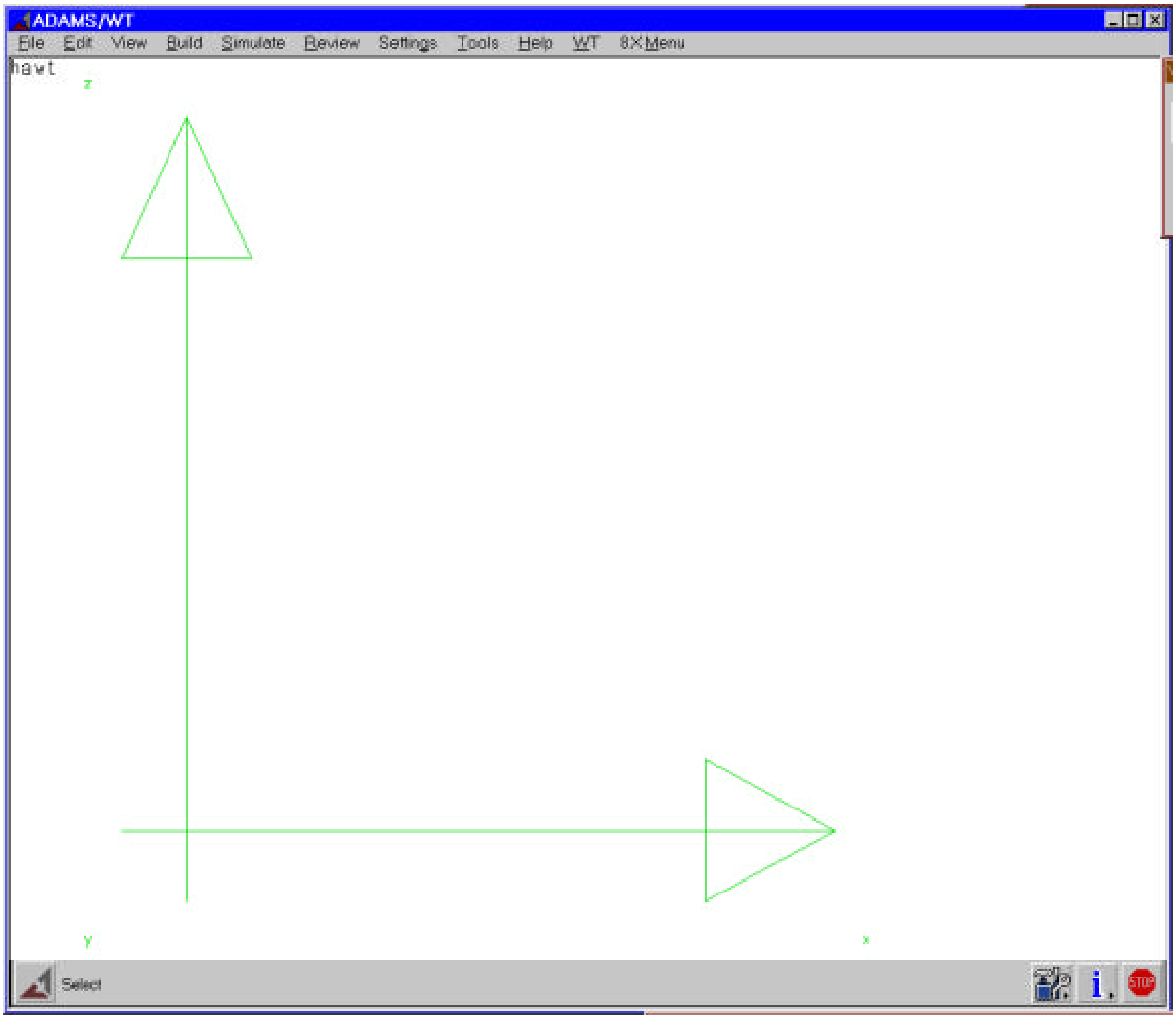
The input data for the *case_2* model is in the *examples/case_2* directory. In it you will also find an ADAMS/View command (*.cmd*) file for the *case_1* model. From the *examples/case_2* directory, bring up ADAMS/View by using the icon or by typing at the system command line:

mdi -c aview ru-s i ex & (UNIX)
or
mdi aview ru-s (NT)

Then start WT by reading in the *wt_main.cmd* command file (which loads the interface code) using the FILE IMPORT menu or from the View command line:

file command read file=wt_main

As always, View commands may be shortened to the minimum unique naming. We suggest that you typically use at least three characters to avoid ambiguities. That would make this command, for example, *"fil com rea fil=wt_main."* This should leave you with the base of the *hawt* model in the view:



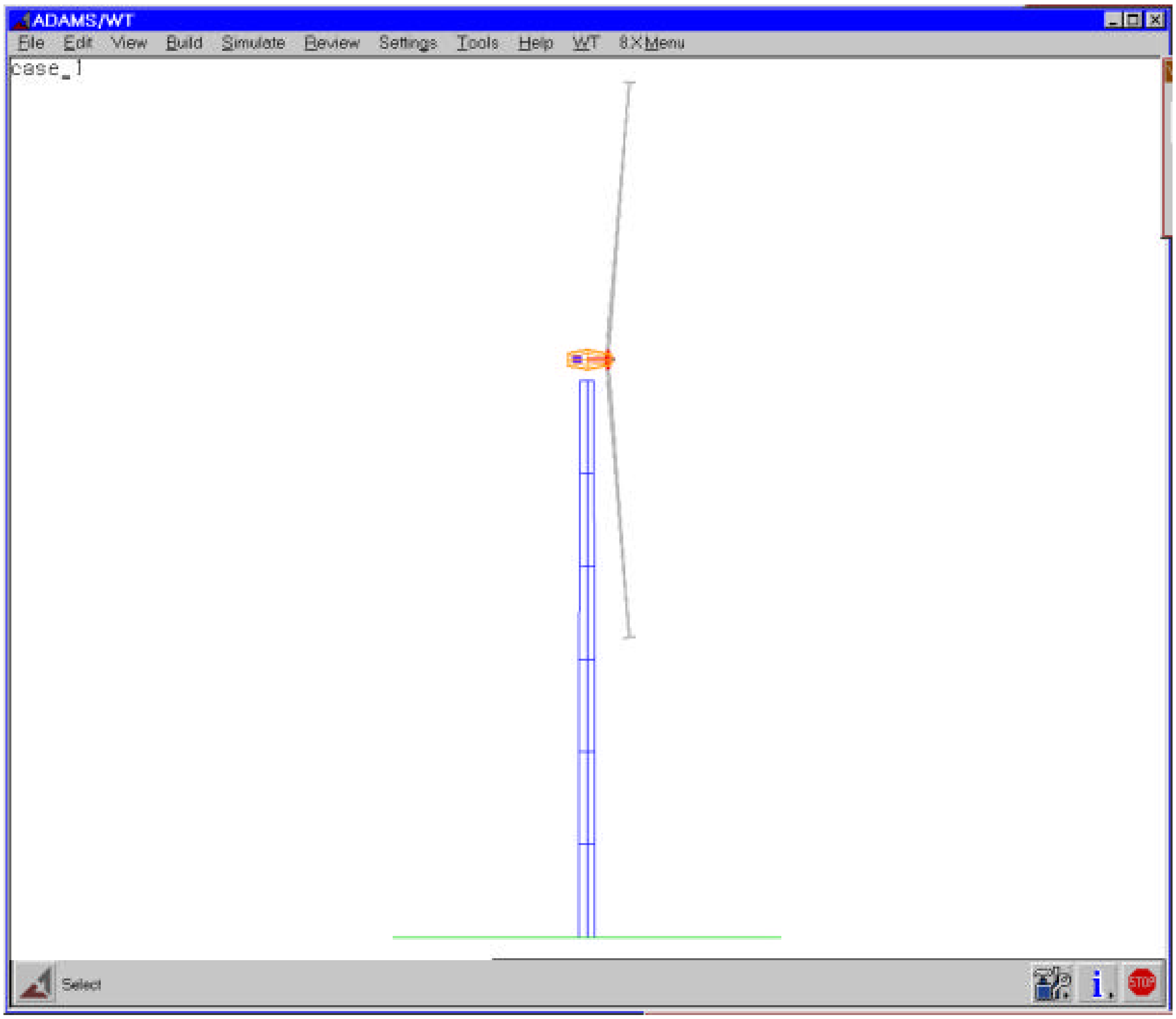
Next you should delete the *hawt* model, either through the main menu structure with BUILD MODEL DELETE or directly at the View command line with

model delete model=hawt

This will leave you with a blank window, into which you can read the command file for the *case_1* example. This can be done through the menus using FILES IMPORT (recommended) or at the command line with:

file command read file=case_1

Note that if you use the command line, the entire process of rebuilding the model will be logged through the dialog window, which can take quite some time. At this point you should have the *case_1* model displayed.



Now change the name of the model, either using the menu structure with BUILD MODEL RENAME, or at the command line with:

model modify model=case_1 new=case_2

At this point you are ready to start in on the necessary modifications. This would be a good place to save your work in a binary image.

8.3 Rotor Blade Removal

The ADAMS/WT interface makes it very easy to remove a rotor blade from your model. It understands whether the blade is rigid or flexible and whether or not there is a tip weight attached. To remove the first blade, use the WT menu structure and select the ROTOR_BLADE DELETE panel, which has only one field. You should enter

Blade Number = 1

and then select Apply (not OK) on the panel. You should see the lower blade in the model disappear.

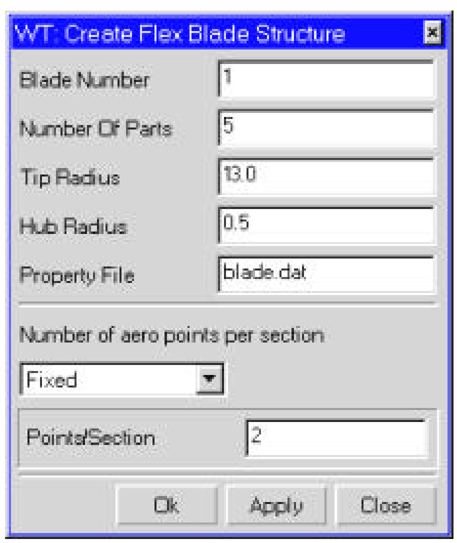
Return to the single field and change it to

Blade Number = 2

You can then select OK on the panel and the upper blade should disappear.

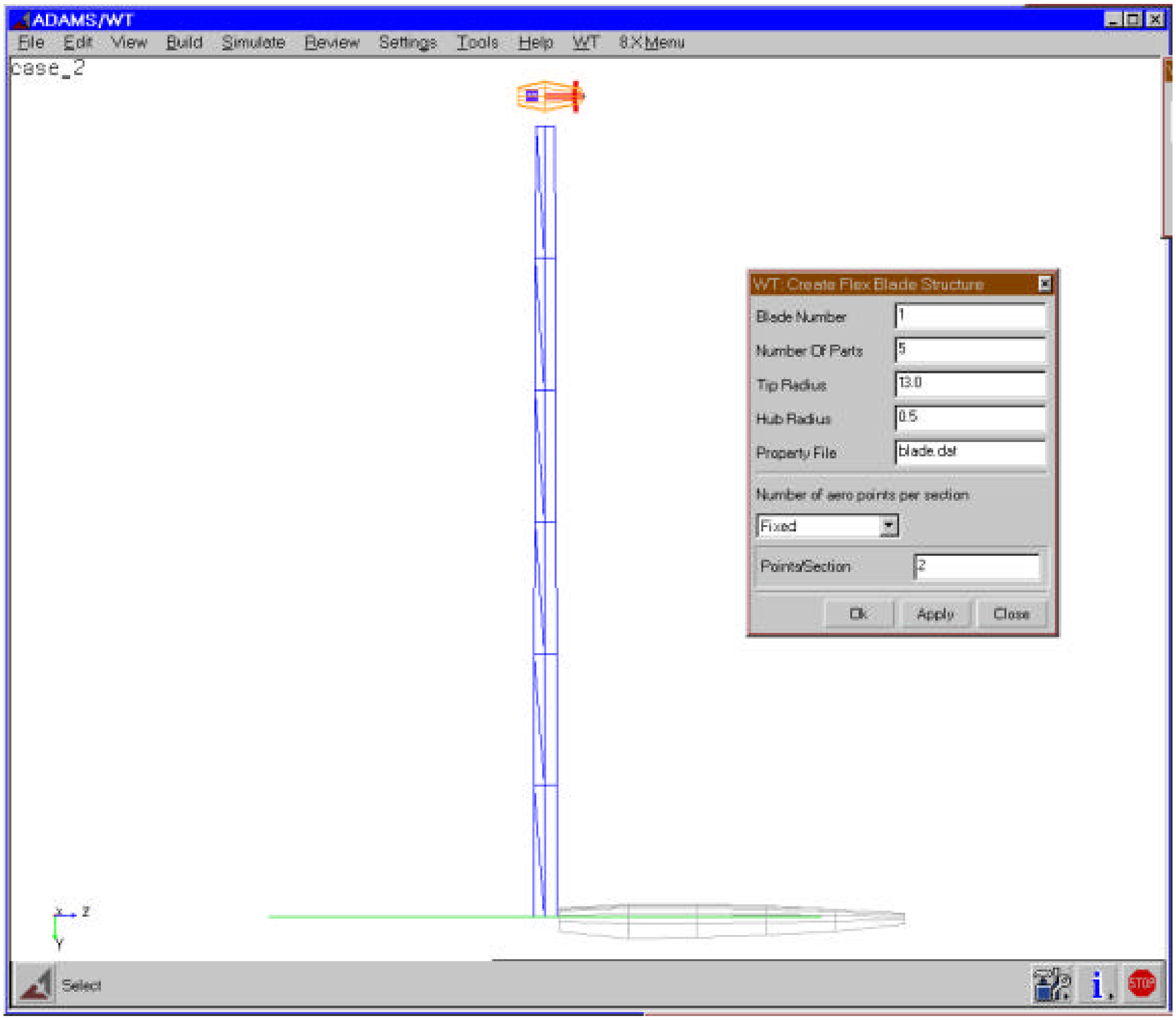
8.4 New Rotor Blades

This example uses a fully flexible blade. The blade data for this case is the same as for case 1, and is found in the *blade.dat* file in the *examples/case_2* directory. Bring up the flexible blade creation panel usaing the Wt menus, ROTOR_BLADE CREATE FLEXIBLE_BLADE STRUCTURAL, and enter the values shown.



7

If everything is working, when you Apply the panel, ADAMS/WT will run the auxiliary program *wtblade*.exe and should display a window which monitors the blade construction, which, due to a problem with A/View 9.1 graphics, could take a few minutes. (Note: Depending on your system configuration, you may need to manually move or link the *wtblade.exe* probram into this *case_2* directory.) The blade is originally constructed on the ground. Note that the aerodynamic center locations are already in place (the *ac##* MARKERs, two per blade element) and the tip is also marked for later attachment of the tip weight.

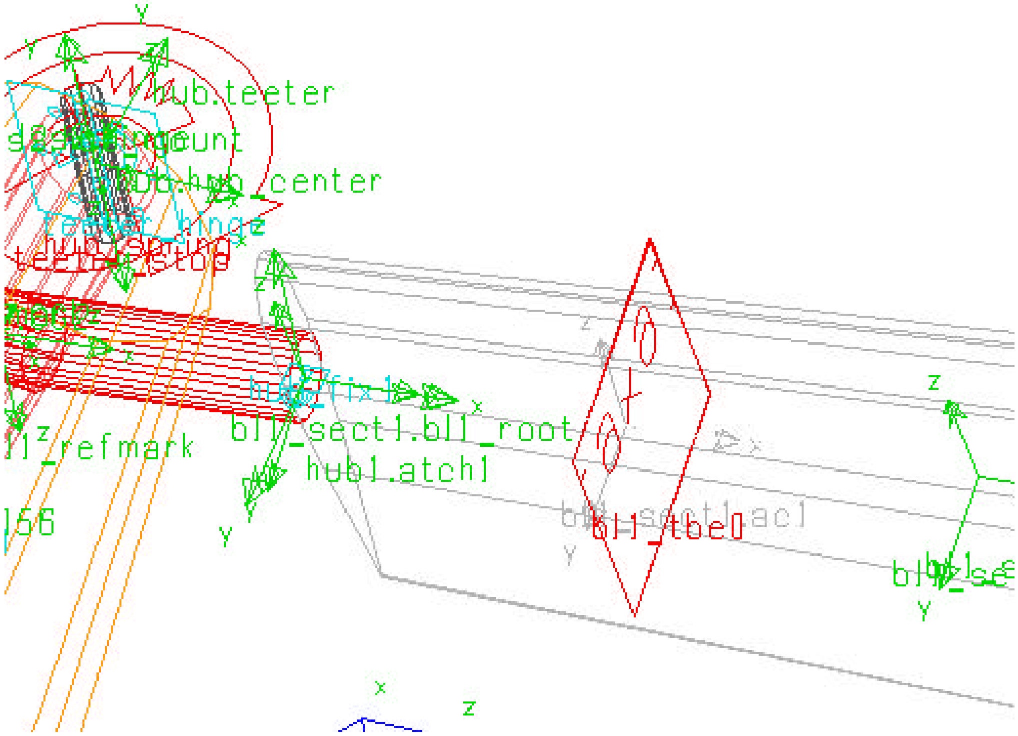


If you Apply'ed the panel instead of OK'ing it, you can create the second blade by just switching to the Blade Number field, entering 2 instead of 1 and then selecting OK. The second blade will be built exactly on top of the first. If you used OK on the first blade, you should again bring up the flexible blade creation panel through the menus, using ROTOR_BLADE CREATE FLEXIBLE_BLADE STRUCTURAL, and use the following values (WT should remember everything except the blade number.):

Blade Number = 2
Number of blade parts = 5
Tip Radius = 13.0 m
Hub Radius = 0.5 m
File of blade properties = blade.dat
Fixed # of Aero_Points per Section = 2

After this, you of course need to relocate the blades to the correct attachment points on the hub. Using the ROTOR_BLADE RELOCATE panel with the following values will both move the first blade to the *atch1* MARKER on the hub and connect it to the hub with a half-length FIELD called *bl1_tbe0*.

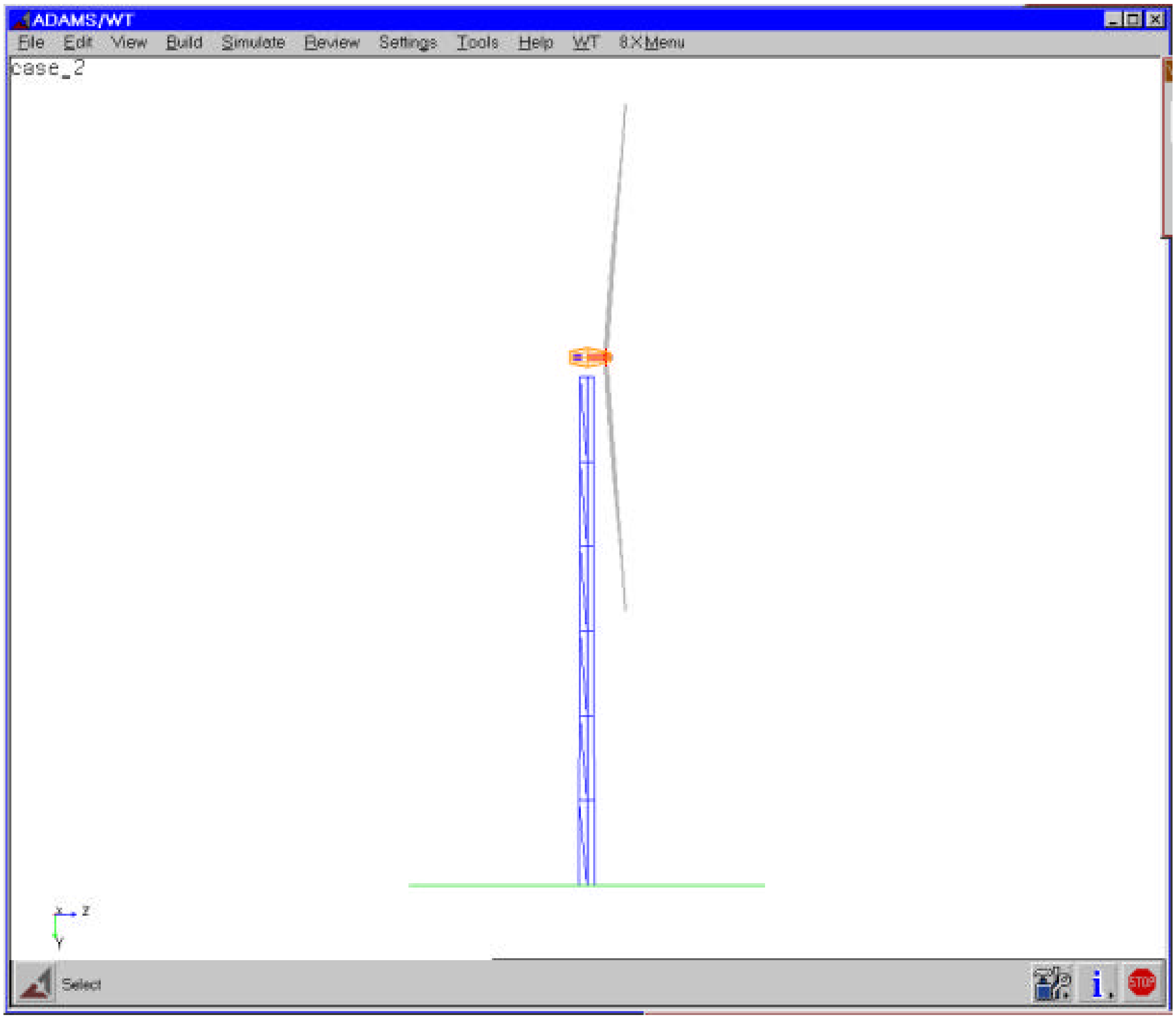
Blade_Number = 1
Base Marker on Blade = bl1_root
Target Location Marker = atch1
Pitch Angle = -10.8 deg



Use the ROTOR_BLADE RELOCATE panel again with the following values to move the second blade to the *atch2* MARKER on the hub and connect it to the hub with a half-length FIELD called *bl2_tbe0*.

Blade_Number = 2
Base Marker on Blade = bl2_root
Target Location Marker = atch2
Pitch Angle = -10.8 deg

Note that here we are using the true pitch angle as it would be measured at the blade root. No correction is necessary for flexible blades. Note also that, by convention, the #1 blade begins in the zero azimuth position, which is pointing straight down. The following graphic has the ADAMS/View icons turned off for clarity.



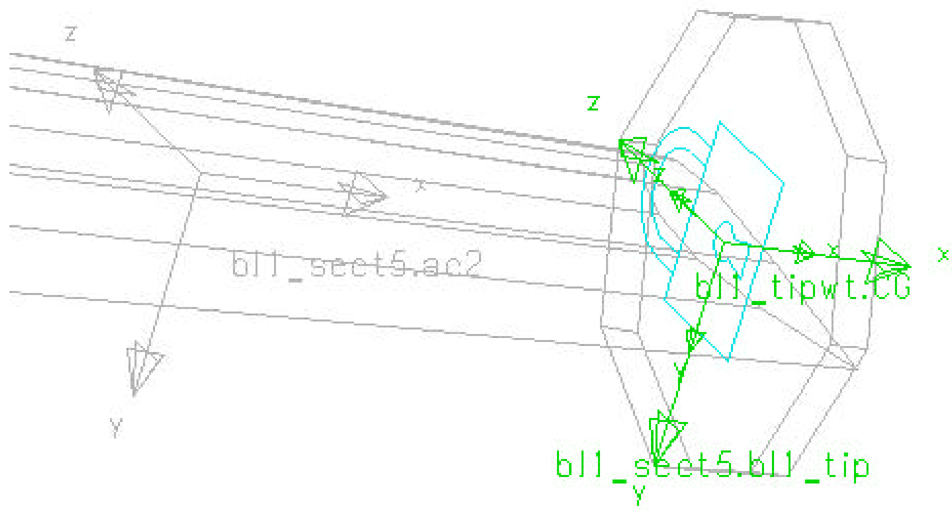
8.5 Tip Weights

This example case uses the same tip weights on both blades as *case_1*.

To add a tip weight to blade #1, bring up the ROTOR_BLADE ADD_TIP_WEIGHT panel and use the following parameters:

> Blade_number = 1
> Ref_marker = bl1_tip
> Mass = 15 kg
> Xcg_offset = Ycg_offset = Zcg_offset = 0.0
> Ixx = 0.1 kg-m^2
> Iyy = Izz = 1.0 kg-m^2

This should change the blade tip to look like this:



After Applying the panel for blade #1, you should change the blade number and reference marker for blade #2 and Apply again. WT should retain the values in the other fields.

Blade_number = 2
Ref_marker = bl2_tip

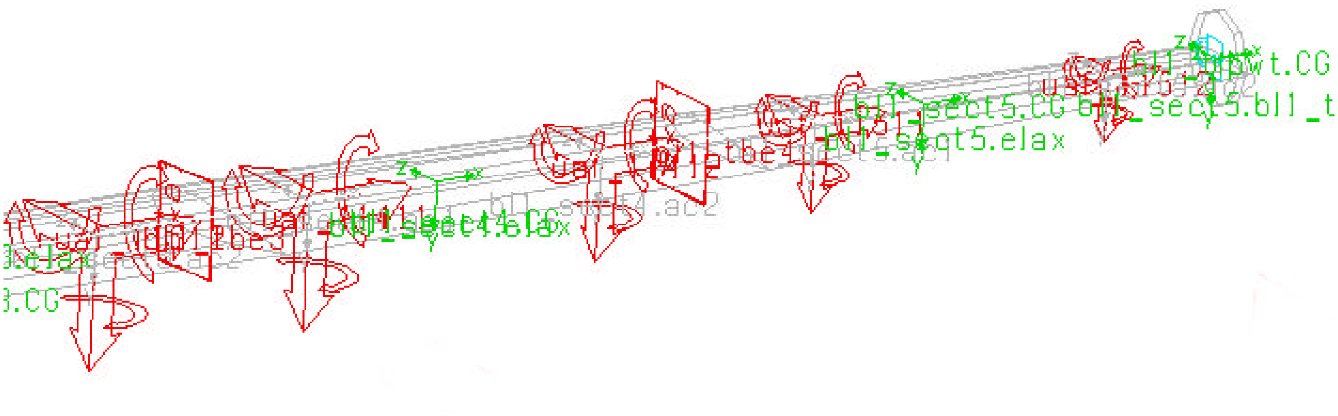
8.6 Aerodynamics

It is no more difficult to add aerodynamics to this model than it was for the rigid-blade model, due to the up-front work done by Craig Hansen's group at the University of Utah, and the automation provided by ADAMS/WT. The AeroDyn aerodynamics subroutines are described in more detail in Appendix H. This version of WT is designed to work with version 11.X of AeroDyn and may not work with other versions.

To add the GFORCE elements which apply the aerodynamic forces computed in the AeroDyn routines to blade #1, you should bring up the AERODYNAMICS AERODYN_AERO FLEXIBLE_BLADE panel and enter the following data:

Blade_Number = 1
Number_of_Sections = 5

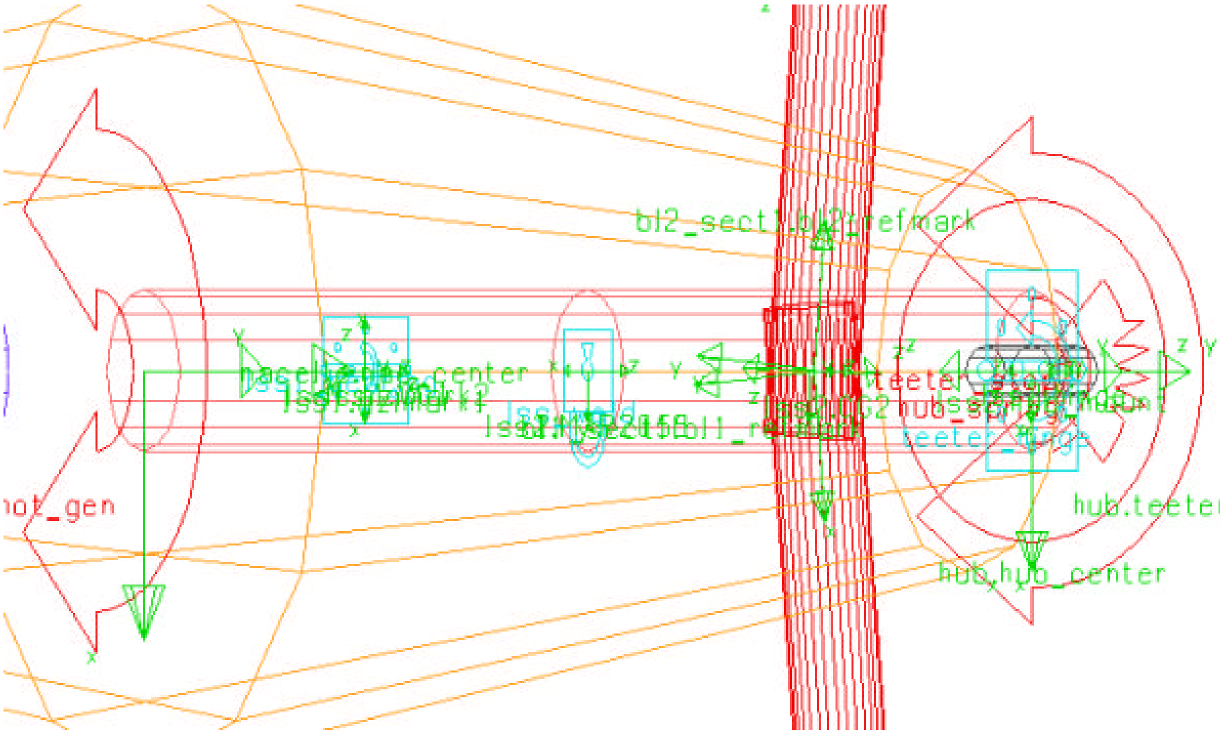
Apply this panel for blade #1 and then change only the Blade_Number field (to 2) and OK the panel for blade #2. Each time you submit the panel, A/View will spend some time doing computations and, if you have the dialog window open, you should then see a series of messages flash past like "The floating marker FMA115120 has been created on the part .case_2.ground." After the aerodynamic GFORCE elements are added, it will be nearly impossible to make out anything on the whole model when the View icons are turned on. By itself, the outer part blade #1 should look like:



The special MARKERs and SENSOR required by AeroDyn should still be in the model from when you imported the *case_1.cmd* version. You will again also need the appropriate input files for AeroDyn. These are the *yawdyn.ipt* and *airfoil.dat* files which can be found in the *examples/case_2* directory. The airfoild data file is identical to the one used for *case_1*. The *yawdyn.ipt* file is similar to the rigid blade file, but reflects the different aerodynamic segment lengths of the flexible blade. The user-executable version of ADAMS/Solver from the first example, which includes the AeroDyn routines, can be re-used to run this model also.

8.7 Low-Speed Shaft Modifications

Before beginning work on the low-speed shaft, it will be useful to zoom in on that part of the model and adjust the view so that the different parts of the shaft are accessible.



The first step is to remove the fixed-type JOINT which connects the two half parts of the shaft. To do this, go through the 8.X Menu structure to JOINT DELETE and pick on the lock icon to select the *lss_weld*. Execute the panel and the joint should disappear. You can, if you wish, also delete the left-over MARKERs from that joint if you wish (not required) using the MARKER DELETE panel and picking on them.

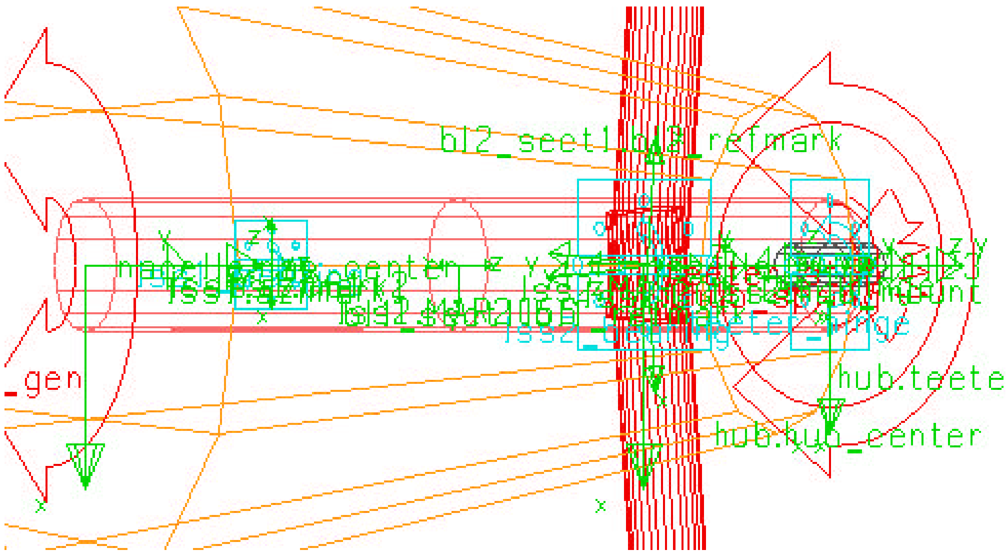
The next step is to create a new revolute JOINT on the *lss2* PART to hold it in place. To do this, go back to the 8.X Menu and select JOINT REVOLUTE CREATE. This brings up a *very* large panel which includes all kinds of friction information that you can safely ignore. Enter just the following data:

joint_name = lss2_bearing
friction enabled = no
POSITION_BY_USING_COORDINATES
i_part_name = lss2
j_part_name = nacelle
location = 0,0,0
orientation = 0,0,0
relative_to = CG2

When you execute this panel, the icon for the *lss2_bearing* may be <u>very</u> large. To reduce the size of the icon to something more reasonable, go back to the Command Navigator and select CONSTRAINT ATTRIBUTES. Pick the *lss2_bearing* and in the second field you should enter

scale_of_icons = 0.5

You can then Apply the panel a few times until the icon size is acceptable. When you are finished, the shaft should look something like this:



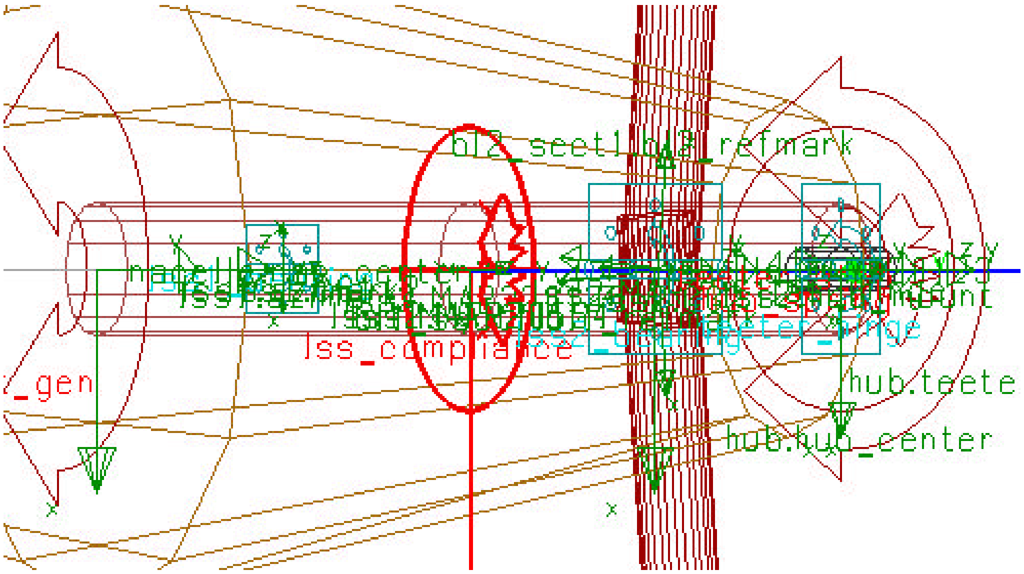
Finally, you need to add an appropriate torsional spring to the shaft. This can be done using the 8.X Menu and selecting for the FORCE ROTAT_SPRING CREATE panel. This can also be done through the WT-Specific Extras menu by selecting Torsion Spring. Regardless of how you get there, you should enter the following data in the panel:

spring_damper_name = lss_compliance
stiffness = 171000 newton/deg
damping = 1710 newton-sec/deg
preload = 0.0
displacement_at_preload = 0.0
POSITION_BY_USING_COORDINATES (or Part Names)
i_part_name = lss1
j_part_name = lss2
location = 0,0,0
orientation = 0,0,0
relative_to = lss2

As for the bearing, when you execute this panel, the icon for the *lss_compliance* may be <u>very</u> large. To reduce the size of the icon to something more reasonable, go back to the Command Navigator and select FORCE ATTRIBUTES. Pick on the *lss_compliance* and in the second field you should enter

- scale_of_icons = 0.5

You can then Apply the panel a few times until the icon size is acceptable. When you are finished, the shaft should look something like this



NOTE: This would be a good time to save your work.

8.8 Output Requests

To get specific information about the torsional response of the low-speed shaft, you should create a special REQUEST for it. To do this, go through the WT menu and select REQUESTs to bring up the Create Requests panel. Check <u>only</u> the box for Low-Speed Shaft and enter *lss_compliance* in the field window. Remember to make sure that <u>only</u> the Low-Speed Shaft box is checked. The other REQUESTs from the *case_1* model are already in the model.

Executing this panel will automatically create two REQUESTs called *lss_forces* and *lss_displ*.

8.9 Running the Simulation

We recommend that you turn off the RESULTS output, since this minimizes the absolute amount of output and speeds the runs significantly. The model <u>should</u> have inherited the RESULTS setting from *case_1*. If you do need to use the results (*.res*) file, writing it UNFORMATTED will be both faster and produce much smaller files than the default FORMATTED output. Details on these options, other output options and integrator parameter selection can be found in the previous chapter in section 7.14.
At this point, your model is complete and you should write it out in dataset (*.adm*) format for simulation and in View binary (*.bin*) and command file (*.cmd*) formats for safekeeping. These

actions may be accomplished from the FILE SAVE and FILE EXPORT menu or from the A/View command line. In the command line window, you can type:

file adams write file=case_2
file command write file=case_2 entity=case_2
file binary write file=case_2

Now you are ready to try your first simulation of the *case_2* turbine. You should copy or move the *wt20.exe* file you created in the first example problem into the *examples/case_2* directory for use with this model. If you did not do the first example, refer now to section 7.14 for instructions on how to build the user-executable version of ADAMS/Solver.

Because you are running a user-executable version of ADAMS/Solver and will need special Solver commands to run it, and because you will often be running many simulations in a row, it is usually more convenient to run the code from the system command line instead of submitting it directly from the ADAMS/View. To do this you should create an ADAMS/Solver command file *(.acf)* to control the simulation. Using your editor, create a text file named *case_2.acf* with the following contents:

```
case_2
case_2
simulate/dynamics, end=0.2, step=100
simulate/dynamics, end=1.0, step=100
simulate/dynamics, end=2.0, step=53
simulate/dynamics, end=3.0, step=53
simulate/dynamics, end=4.0, step=53
simulate/dynamics, end=5.0, step=53
simulate/dynamics, end=6.0, step=53
simulate/dynamics, end=7.0, step=53
simulate/dynamics, end=8.0, step=53
simulate/dynamics, end=9.0, step=53
simulate/dynamics, end=10.0, step=53
stop
```

To run the code you can again use the menu interface step by step, or enter the single long command at the system prompt:

mdi -c ru-u i wt20.exe case_2.acf exit

or for NT

mdi ru-u wt20.exe case_2.acf

At this point, ADAMS/Solver should start up and the simulation progress should be displayed on screen. You can expect some difficulty with simulation startup, and perhaps some warning messages about corrector convergence during the run, but these can both be ignored as long as the simulation recovers. The program log is also written to the file *case_2.msg*. When the run is complete, you should be returned to the system prompt and the simulation results should be in the files *case_2.gra* and *case_2.req*. The *.msg* file should contain something very similar to this:

```
****************************************************************
```

```
    *                                                            *
    *                 Mechanical Dynamics, Inc.                  *
    *                                                            *
    *                        A D A M S                           *
    *                                                            *
    *      Automatic Dynamic Analysis of Mechanical Systems      *
    *                                                            *
    *                       Version 9.1                          *
    *                                                            *
    *  ADAMS/Solver, ADAMS/Android, ADAMS/Animation, ADAMS/FEA,  *
    *  ADAMS/Real-Time Kinematics, ADAMS/Vehicle, ADAMS/View,    *
    *      Collectively known as the ADAMS Product Line          *
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    *  disclosure by the  Government is subject to restrictions  *
    *  as set forth in subparagraph (c)(1)(ii) of the Rights in  *
    *  Technical   Data   and   Computer   Software  clause  at  *
    *  252.227-7013,  as amended.   Title  to all  intellectual  *
    *                 property remains with MDI.                 *
    *                                                            *
    **************************************************************
    **************************************************************
    *                                                            *
    *                  A D A M S / S o l v e r                   *
    *                                                            *
    *        08:38:27 25-DEC-98            Version 9.1           *
    *                                                            *
    *                                                            *
    **************************************************************


 OUTFOP:IN_FILENM
      ADAMS model file .. case_2.adm

 OUTFOP:OUT_FILES

    Default file names for output files

      Tabular output file:
      case_2.out

      Diagnostic file    :
      case_2.msg

      Message Database file    :
      case_2.mdb

      Graphics file      :
      case_2.gra

      Request file       :
      case_2.req

      Femdata file       :
      case_2.fem

      Results file       :
      case_2.res


 INVIEW:READMDL
    Input Phase - Reading in Model


 INVIEW:MESSAGE91
    ***********************************************************
    ADAMS/Solver dataset Title:
    ADAMS/View model name: case_2
    ***********************************************************
```

```
INVIEW:READ_MDL
   Reading of model complete.


INBASE:DATABASE
   Input Phase - Populating Solver database


INBASE:INP_DONE
   Input Phase Complete.


MEKINP:CPUTIME
   CPU time is 0.33048 seconds.

USRMES:USER
    SENSUB called with no errors
   ID = 1

USRMES:USER
   AeroDyn Version 11.0, University of Utah
   ID = 1

USRMES:USER
   AWT-26 ADAMS model using University of Utah aerodynamics routines v10.0
   ID = 4

USRMES:USER
    Dynamic inflow theory not used in the analysis
   ID = 5

USRMES:USER
   Only 1 line in wind file, steady wind conditions used
   ID = 7

USRMES:USER
   Detected system force units of Newtons
   ID = 1

VERINP:END_INPUT
   Input and Input Check Phase complete.

GTMODE:NUMB_DOFS
   The system has 100 kinematic degrees of freedom.

GLGETL:USER_CMND
   sim/dyn,end=0.2,step=100

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                             Default  |Recommended|Selected
                          |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06


ICCALC:DISPL
   Displacement initial condition analysis...

CODGEN:JAC_STAT

   Jacobian Matrix Statistics for the Initial Conditions
   ======================================================
   Number of equations ............ = 200
   Number of non-zero entries ...... = 822
   Percentage of matrix non-zero ... = 2.0550
   Total space used in MD array .... = 90422


ICCALC:VELO
   Velocity initial condition analysis...

CODGEN:JAC_STAT

   Jacobian Matrix Statistics for the Initial Conditions
   ======================================================
   Number of equations ............ = 200
   Number of non-zero entries ...... = 972
   Percentage of matrix non-zero ... = 2.430
   Total space used in MD array .... = 90994
```

```
ICCALC:ACCEL
   Acceleration initial condition analysis...

CODGEN:JAC_STAT

   Jacobian Matrix Statistics for the Initial Conditions
   ======================================================
   Number of equations ............ = 520
   Number of non-zero entries ...... = 3053
   Percentage of matrix non-zero ... = 1.1291
   Total space used in MD array .... = 113132


SYMBLU:DISP_VELO
   Generating the Jacobian matrix for the displacements and velocities.

CODGEN:JAC_STAT

   Jacobian Matrix Statistics for the Initial Conditions
   ======================================================
   Number of equations ............ = 200
   Number of non-zero entries ...... = 822
   Percentage of matrix non-zero ... = 2.0550
   Total space used in MD array .... = 90624


SYMBLU:ACCELRATN
   Generating the Jacobian matrix for the accelerations and forces.

CODGEN:JAC_STAT

   Jacobian Matrix Statistics for the Initial Conditions
   ======================================================
   Number of equations ............ = 520
   Number of non-zero entries ...... = 3053
   Percentage of matrix non-zero ... = 1.1291
   Total space used in MD array .... = 123252


SYMBLU:DYNAMICS
   Generating the Jacobian matrix for the dynamics problem.

CODGEN:JAC_STAT

   Jacobian Matrix Statistics for a Dynamic Analysis
   ======================================================
   Number of equations ............ = 745
   Number of non-zero entries ...... = 6495
   Percentage of matrix non-zero ... = 1.1702
   Total space used in MD array .... = 213462

    Simulation        Time         Cumulative    Cumulative     Integrator
       Time           Step         Iterations    Steps Taken      Order
    ___________    ___________    __________    ___________    __________
    0.00000E+00    1.00000E-04         0             0              1

CORRCT:NO_INCRE

 ---- WARNING ----
   The corrector has failed to converge at t = 2.0E-03 with a poorly
   conditioned Jacobian matrix.  The stepsize 9.50E-04 cannot be
   increased beyond the maximum 9.50E-04 .

CORRCT:NO_INCRE

 ---- WARNING ----
   The corrector has failed to converge at t = 2.0E-03 with a poorly
   conditioned Jacobian matrix.  The stepsize 7.1250E-04 cannot be
   increased beyond the maximum 7.1250E-04 .

CORRCT:NO_INCRE

 ---- WARNING ----
   The corrector has failed to converge at t = 2.0E-03 with a poorly
   conditioned Jacobian matrix.  The stepsize 5.34375E-04 cannot be
   increased beyond the maximum 5.34375E-04 .
    2.00000E-03    4.34180E-04        84             6              1
    2.00000E-02    2.00000E-03       255            21              1
    4.00000E-02    2.00000E-03       326            33              1
    6.00000E-02    2.00000E-03       357            43              2
    8.00000E-02    2.00000E-03       387            53              2
    1.00000E-01    2.00000E-03       417            63              3
    1.20000E-01    2.00000E-03       446            73              2
    1.40000E-01    2.00000E-03       474            83              3
    1.60000E-01    2.00000E-03       504            93              2
    1.80000E-01    2.00000E-03       534           103              2
    2.00000E-01    2.00000E-03       564           113              2

GLGETL:USER_CMND
   sim/dyn,end=1,step=100

DBANNR:BDF
```

```
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                        |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation         Time         Cumulative    Cumulative     Integrator
       Time            Step         Iterations    Steps Taken      Order
    ___________     ___________     __________    ___________    __________
    2.00000E-01     4.00000E-04        564           113            2
    2.08000E-01     6.00000E-03        570           115            2
    2.80000E-01     8.00000E-03        597           124            3
    3.60000E-01     8.00000E-03        627           134            2
    4.40000E-01     8.00000E-03        651           144            2
    5.20000E-01     8.00000E-03        672           154            2
    6.00000E-01     8.00000E-03        693           164            2
    6.80000E-01     8.00000E-03        713           174            3
    7.60000E-01     8.00000E-03        734           184            2
    8.40000E-01     8.00000E-03        754           194            3
    9.20000E-01     8.00000E-03        775           204            2
    1.00000E+00     8.00000E-03        797           214            2

GLGETL:USER_CMND
   sim/dyn,end=2,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                        |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation         Time         Cumulative    Cumulative     Integrator
       Time            Step         Iterations    Steps Taken      Order
    ___________     ___________     __________    ___________    __________
    1.00000E+00     9.43396E-04        797           214            2
    1.01887E+00     1.08679E-02        802           216            2
    1.11321E+00     1.88679E-02        817           221            2
    1.22642E+00     1.88679E-02        834           227            3
    1.33962E+00     1.88679E-02        848           233            4
    1.45283E+00     1.88679E-02        860           239            3
    1.56604E+00     1.88679E-02        872           245            3
    1.67925E+00     1.88679E-02        884           251            4
    1.79245E+00     1.88679E-02        901           257            3
    1.90566E+00     1.88679E-02        919           263            3

GLGETL:USER_CMND
   sim/dyn,end=3.0,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                        |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation         Time         Cumulative    Cumulative     Integrator
```

```
     Time            Step         Iterations    Steps Taken      Order
  ___________      ___________    __________    ___________    __________
  2.00000E+00      9.43396E-04       934           268            3
  2.01887E+00      1.88679E-02       937           269            3
  2.11321E+00      1.88679E-02       952           274            3
  2.22642E+00      1.88679E-02       970           280            3
  2.33962E+00      1.88679E-02       988           286            3
  2.45283E+00      1.88679E-02      1006           292            3
  2.56604E+00      1.88679E-02      1023           298            4
  2.67925E+00      1.88679E-02      1041           304            3
  2.79245E+00      1.88679E-02      1059           310            4
  2.90566E+00      1.88679E-02      1077           316            3

GLGETL:USER_CMND
   sim/dyn,end=4,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                            Default  |Recommended|Selected
                         |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

  Simulation         Time         Cumulative    Cumulative     Integrator
     Time            Step         Iterations    Steps Taken      Order
  ___________      ___________    __________    ___________    __________
  3.00000E+00      9.43396E-04      1092           321            3
  3.01887E+00      1.88679E-02      1095           322            3
  3.11321E+00      1.88679E-02      1113           328            3
  3.22642E+00      1.88679E-02      1131           334            4
  3.33962E+00      1.88679E-02      1149           340            4
  3.45283E+00      1.88679E-02      1167           346            4
  3.56604E+00      1.88679E-02      1189           352            3
  3.67925E+00      1.88679E-02      1217           358            3
  3.79245E+00      1.88679E-02      1244           364            5
  3.90566E+00      1.88679E-02      1267           370            4

GLGETL:USER_CMND
   sim/dyn,end=5,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                            Default  |Recommended|Selected
                         |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

  Simulation         Time         Cumulative    Cumulative     Integrator
     Time            Step         Iterations    Steps Taken      Order
  ___________      ___________    __________    ___________    __________
  4.00000E+00      9.43396E-04      1283           375            4
  4.01887E+00      1.88679E-02      1286           376            3
  4.11321E+00      1.88679E-02      1306           381            4
  4.22642E+00      1.88679E-02      1330           387            3
  4.33962E+00      1.88679E-02      1350           393            3
  4.45283E+00      1.88679E-02      1374           399            4
  4.56604E+00      1.88679E-02      1396           405            4
  4.67925E+00      1.88679E-02      1420           411            4
  4.79245E+00      1.88679E-02      1442           417            4
  4.90566E+00      1.88679E-02      1465           423            4

GLGETL:USER_CMND
   sim/dyn,end=6,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.
```

```
DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation        Time        Cumulative    Cumulative     Integrator
       Time           Step        Iterations    Steps Taken      Order
    ___________    ___________    __________    ___________    __________
    5.00000E+00    9.43396E-04       1484           428             5
    5.01887E+00    1.88679E-02       1487           429             4
    5.11321E+00    1.88679E-02       1507           434             4
    5.22642E+00    1.88679E-02       1531           440             4
    5.33962E+00    1.88679E-02       1555           446             3
    5.45283E+00    1.88679E-02       1579           452             4
    5.56604E+00    1.88679E-02       1604           458             4
    5.67925E+00    1.88679E-02       1628           464             4
    5.79245E+00    1.88679E-02       1650           470             4
    5.90566E+00    1.88679E-02       1672           476             5

GLGETL:USER_CMND
   sim/dyn,end=7,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation        Time        Cumulative    Cumulative     Integrator
       Time           Step        Iterations    Steps Taken      Order
    ___________    ___________    __________    ___________    __________
    6.00000E+00    9.43396E-04       1692           481             5
    6.01887E+00    1.88679E-02       1696           482             4
    6.11321E+00    1.88679E-02       1716           487             3
    6.22642E+00    1.88679E-02       1740           493             4
    6.33962E+00    1.88679E-02       1761           499             5
    6.45283E+00    1.88679E-02       1785           505             5
    6.56604E+00    1.88679E-02       1812           511             4
    6.67925E+00    1.88679E-02       1836           517             4
    6.79245E+00    1.88679E-02       1860           523             4
    6.90566E+00    1.88679E-02       1884           529             4

GLGETL:USER_CMND
   sim/dyn,end=8,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation        Time        Cumulative    Cumulative     Integrator
       Time           Step        Iterations    Steps Taken      Order
    ___________    ___________    __________    ___________    __________
    7.00000E+00    9.43396E-04       1903           534             4
    7.01887E+00    1.88679E-02       1907           535             4
    7.11321E+00    1.88679E-02       1930           542             3
    7.22642E+00    1.88679E-02       1952           548             3
```

```
    7.33962E+00      1.88679E-02       1975            554           5
    7.45283E+00      1.88679E-02       1995            560           4
    7.56604E+00      1.88679E-02       2016            566           3
    7.67925E+00      1.88679E-02       2040            572           3
    7.79245E+00      1.88679E-02       2062            578           4
    7.90566E+00      1.88679E-02       2084            584           4

GLGETL:USER_CMND
   sim/dyn,end=9,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation         Time         Cumulative    Cumulative     Integrator
       Time            Step         Iterations    Steps Taken      Order
    ___________      ___________    __________    ___________    __________
    8.00000E+00      9.43396E-04       2099            589           4
    8.01887E+00      1.88679E-02       2103            590           5
    8.11321E+00      1.88679E-02       2124            595           3
    8.22642E+00      1.88679E-02       2148            601           3
    8.33962E+00      1.88679E-02       2172            607           4
    8.45283E+00      1.88679E-02       2195            613           4
    8.56604E+00      1.88679E-02       2219            619           3
    8.67925E+00      1.88679E-02       2243            625           3
    8.79245E+00      1.88679E-02       2267            631           5
    8.90566E+00      1.88679E-02       2291            637           4

GLGETL:USER_CMND
   sim/dyn,end=10,step=53

DBANNR:BDF
   Begin the dynamic analysis.

   The system is modelled with DAEs.
   The VARIABLE coefficient BDF method will be used.

DBANNR:BDF_TABLE
   The operating values of the error tolerances for BDF are:

                           Default  |Recommended|Selected
                        |-----------|-----------|--------
         Integration error |           |           |
                 NTREL_ERR |  1.00E-03 |  -------  |  1.00E-03
                 NTABS_ERR |  1.00E-03 |  -------  |  1.00E-03
                           |           |           |
         Corrector error   |           |           |
                 CRREL_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06
                 CRABS_ERR |  1.00E-06 |  1.00E-06 |  1.00E-06

    Simulation         Time         Cumulative    Cumulative     Integrator
       Time            Step         Iterations    Steps Taken      Order
    ___________      ___________    __________    ___________    __________
    9.00000E+00      9.43396E-04       2309            642           4
    9.01887E+00      1.88679E-02       2313            643           4
    9.11321E+00      1.88679E-02       2339            651           3
    9.22642E+00      1.88679E-02       2363            657           3
    9.33962E+00      1.88679E-02       2387            663           4
    9.45283E+00      1.88679E-02       2410            669           4
    9.56604E+00      1.88679E-02       2433            675           3
    9.67925E+00      1.88679E-02       2457            681           3
    9.79245E+00      1.88679E-02       2481            687           5
    9.90566E+00      1.88679E-02       2505            693           4

GLGETL:USER_CMND
   stop

TERM0:EXE_TERM

      ADAMS/Solver execution terminated by subprogram A3TERM


TERM0:CP_TIME
   CPU time used = 68.599 seconds
```

8.10 Visualizing the Results

At this point, you are ready to read the results of the simulation back into ADAMS/View to look at the responses. Switch back to the A/View window and either use the FILE IMPORT menu or enter at the View command line:

file analysis read file=case_2 model=case_2

It will take View a few moments to read in the data from the graphics (*case_2.gra*) and request (*case_2.req*) files. You may get an warning message about a missing *.res* file, which you can ignore. You can then animate the results and see how the rotor responded. There are quite a few ways to animate response in View. The simplest way in the WT interface is to bring up the control panel and just hit the ANIMATE button.

8.11 Plotting Output

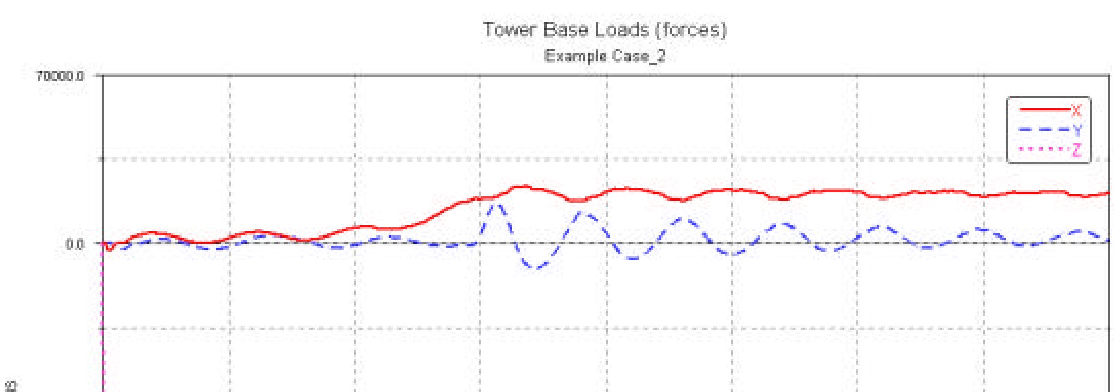
ADAMS/View 9.1 has a completely new plotting interface, including a large number of plotting features which can be accessed in many ways. Quick plots of request data can be made by easily made using the Plot Builder. The data can also be "surfed" this way.

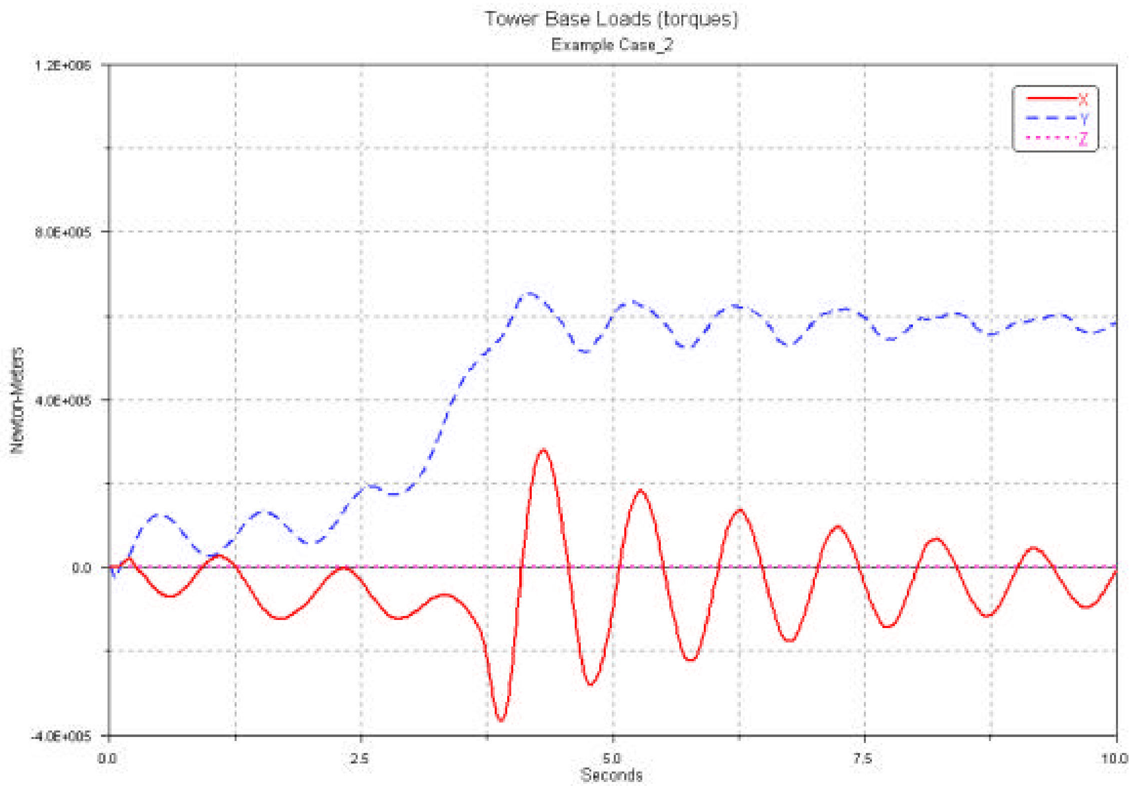
For repetitive plotting of specific requests from multiple simulations, it is often best to create a View command file (*.cmd*) containing the necessary commands to create and customize all the plots for a particular run. This command file contains the same commands you could execute via the plot builder or type in at the View command line to create the plots, but is easily modifiable using a text editor for customization and changes. An example of such a command file is found in the file *plotemup.cmd* in the *examples/case_2* directory. The contents are listed in detail in section 7.17, with the only differences being a change between Case 1 and Case 2 in the subtitle and the addition of the plot of the torsional response of the shaft..

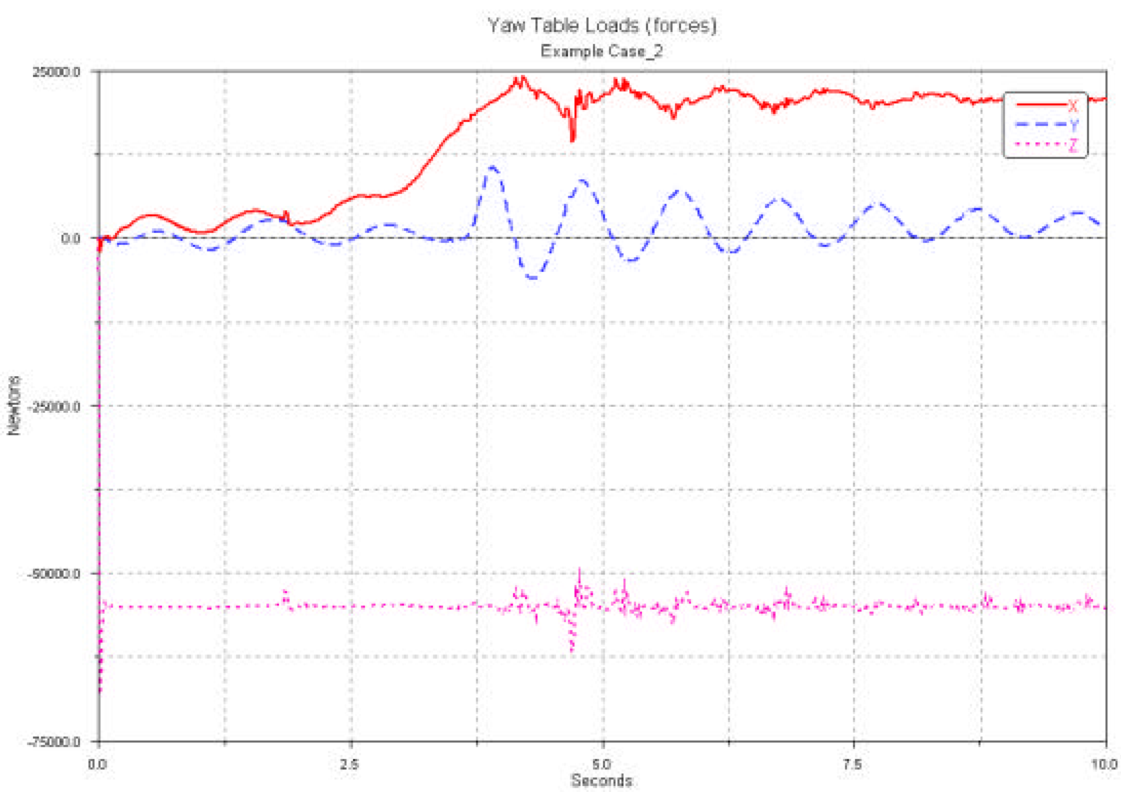
You can read in and run this command file through the FILE IMPORT menus or by entering at the View command line:

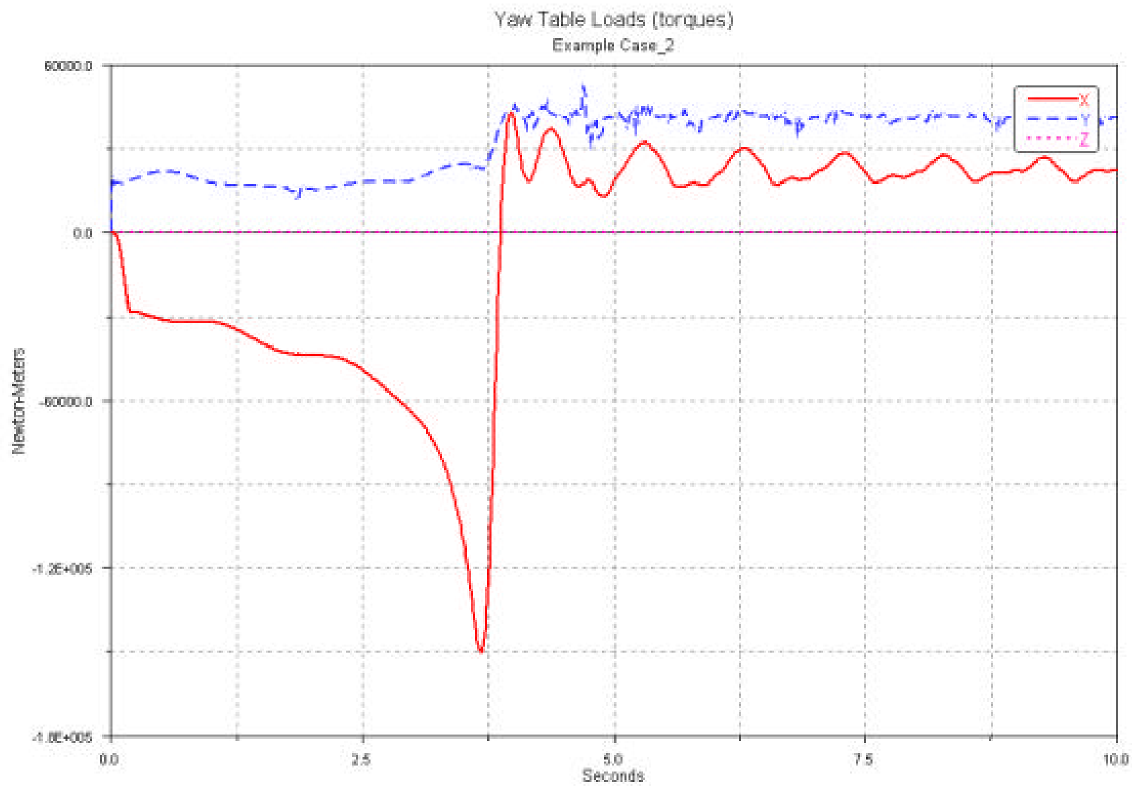
file command read file=plotemup

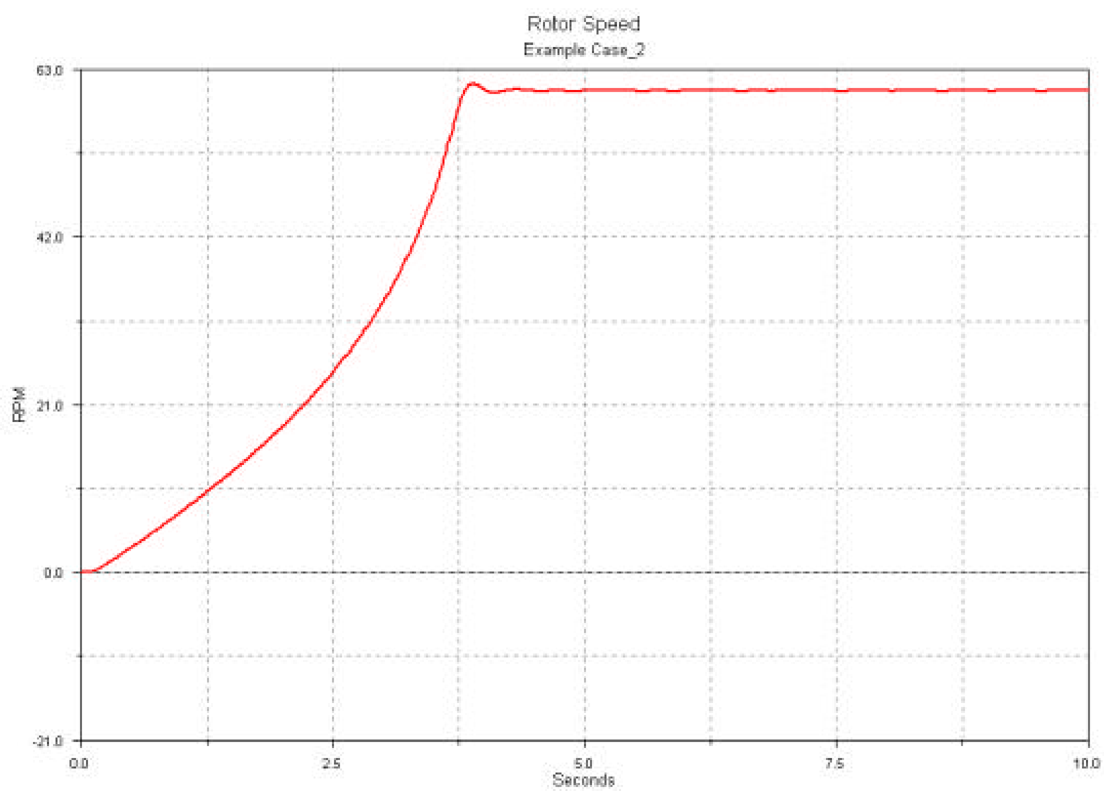
The example plots below can be used to confirm that your model and WT executable are working correctly

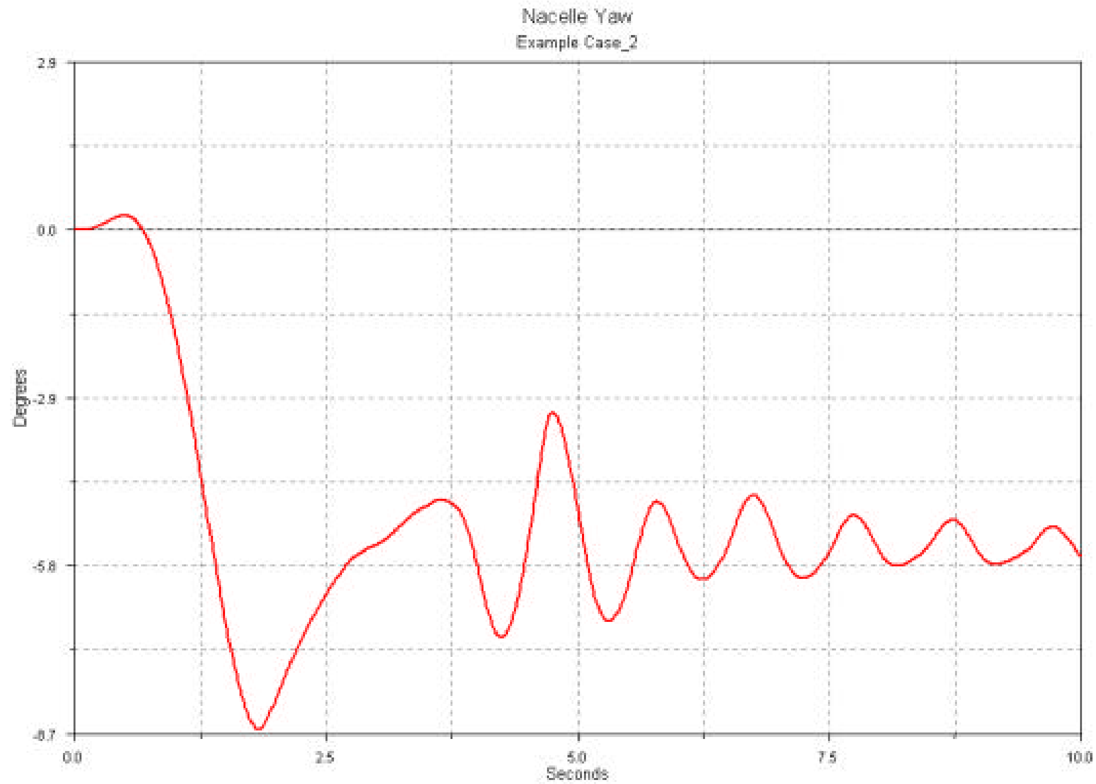


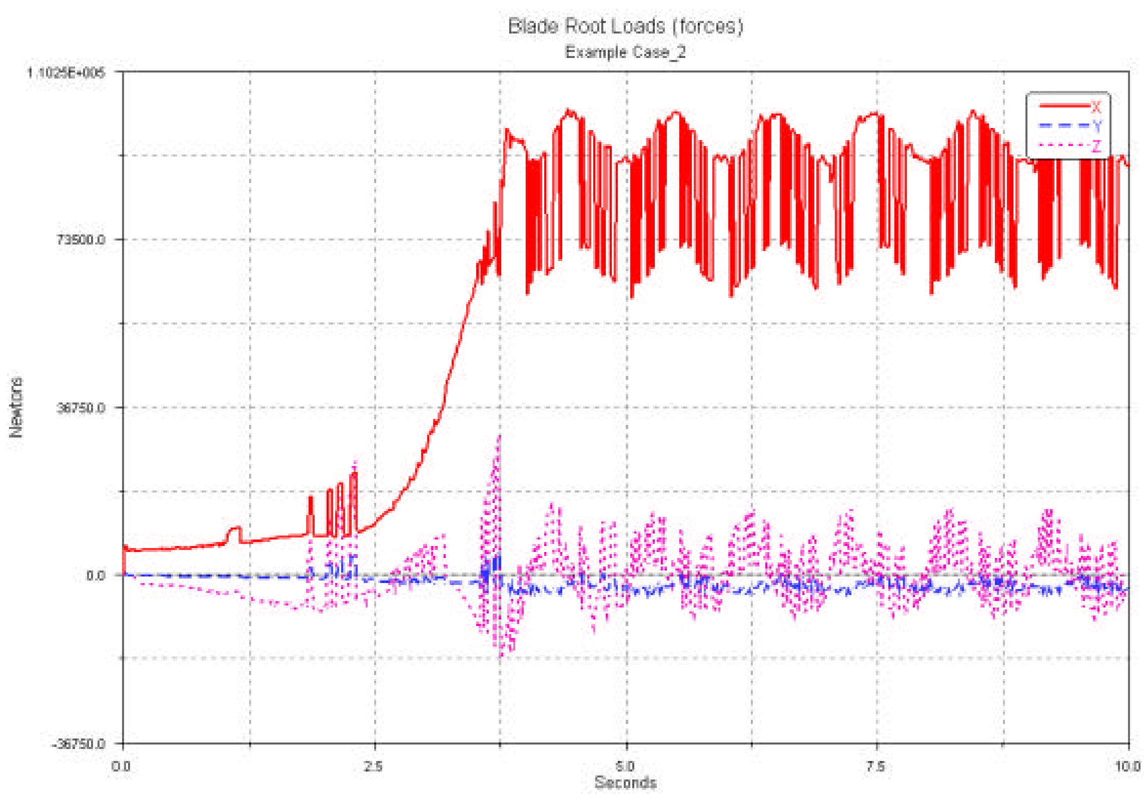

Tower Base Loads (torques)
Example Case_2
Newton-Meters
Seconds
X
Y
Z
1.2E+006
8.0E+005
4.0E+005
0.0
-4.0E+005
0.0
2.5
5.0
7.5
10.0

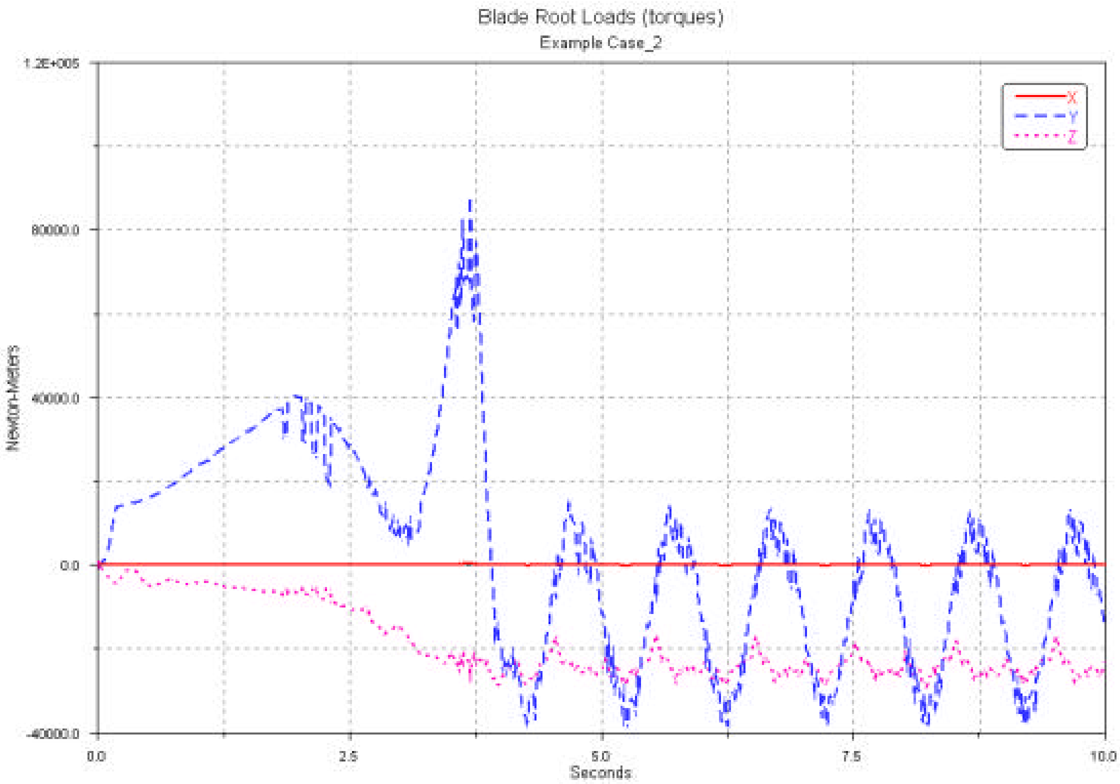

Yaw Table Loads (forces)
Example Case_2
Newtons
Seconds
X
Y
Z
25000.0
0.0
-25000.0
-50000.0
-75000.0
0.0
2.5
5.0
7.5
10.0

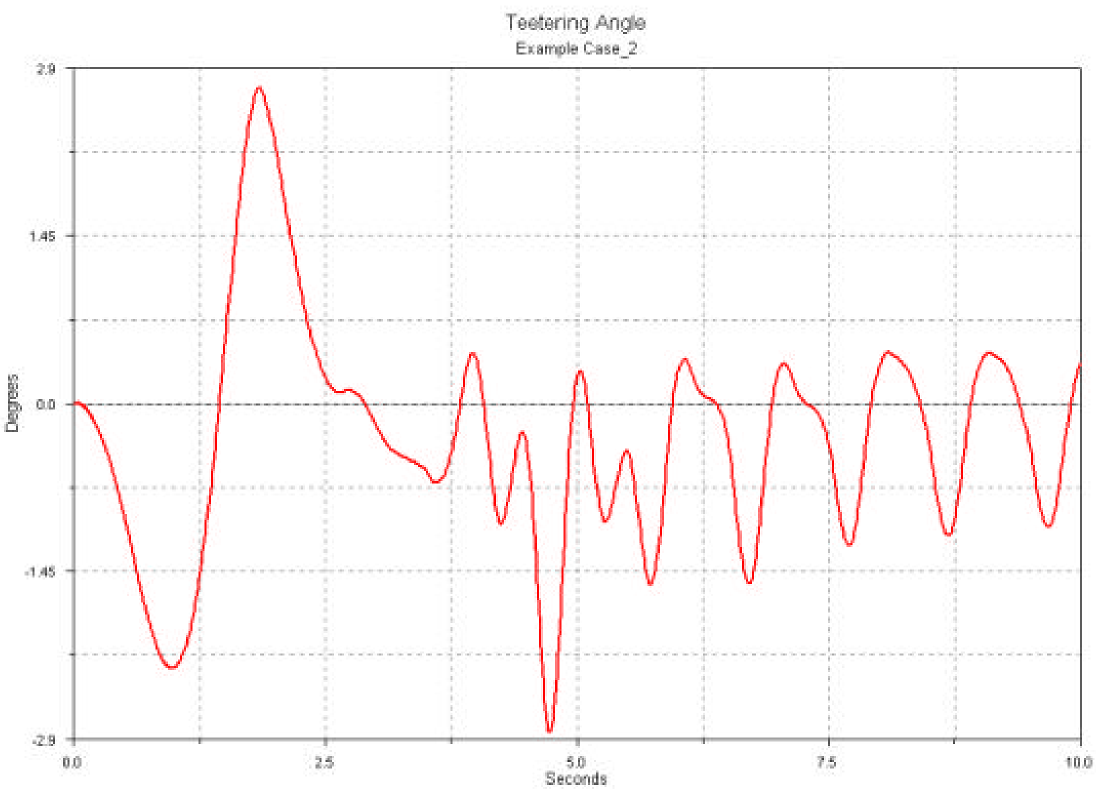

Yaw Table Loads (torques)
Example Case_2
60000.0
0.0
-60000.0
-1.2E+005
-1.8E+005
Newton-Meters
X
Y
Z
0.0
2.5
5.0
7.5
10.0
Seconds

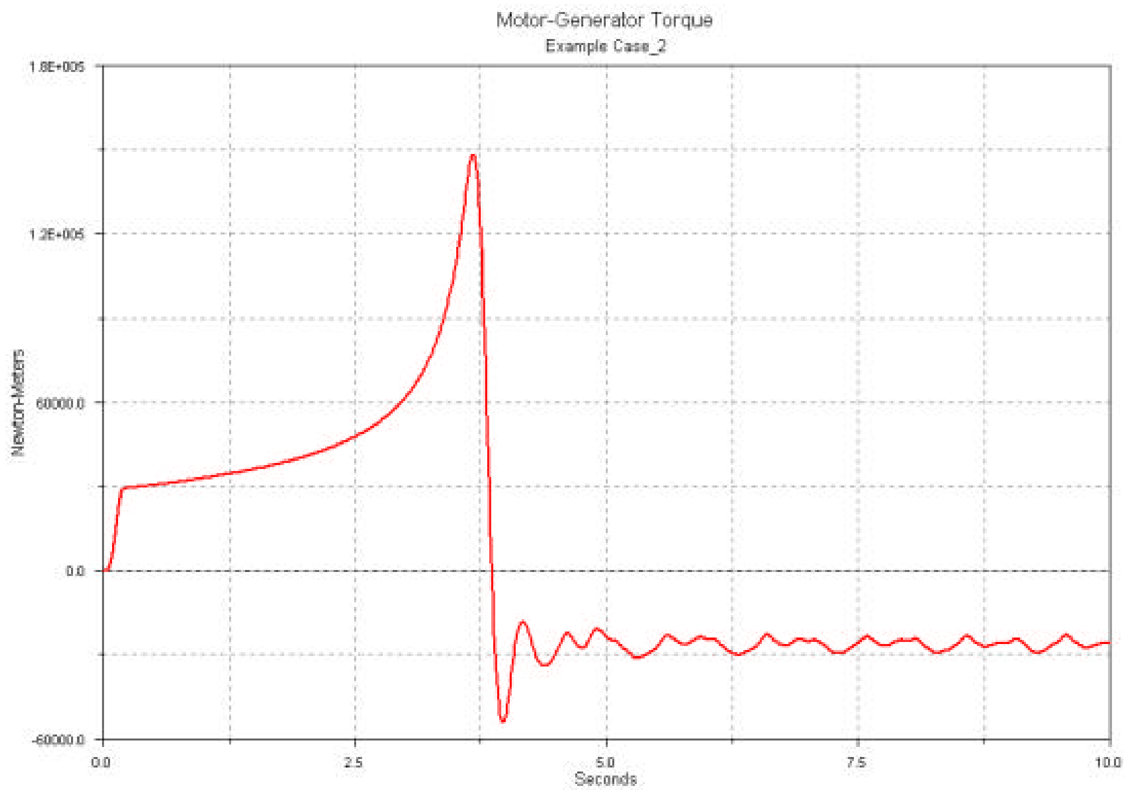

Rotor Speed
Example Case_2
63.0
42.0
21.0
0.0
-21.0
RPM
0.0
2.5
5.0
7.5
10.0
Seconds

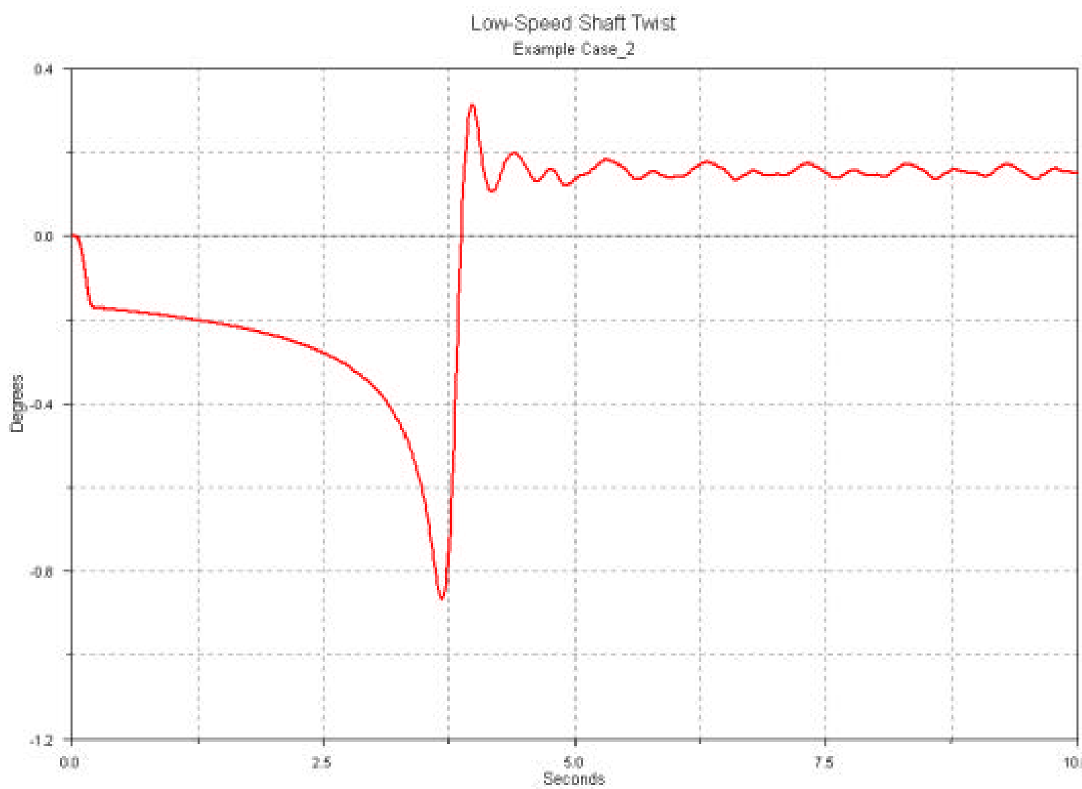

Nacelle Yaw
Example Case_2
2.9
0.0
-2.9
-5.8
-8.7
Degrees
0.0
2.5
5.0
7.5
10.0
Seconds


Blade Root Loads (forces)
Example Case_2
1.1025E+005
73500.0
36750.0
0.0
-36750.0
Newtons
X
Y
Z
0.0
2.5
5.0
7.5
10.0
Seconds


Blade Root Loads (torques)
Example Case_2
1.2E+005
80000.0
40000.0
0.0
-40000.0
Newton-Meters
X
Y
Z
0.0
2.5
5.0
7.5
10.0
Seconds


Teetering Angle
Example Case_2
2.9
1.45
0.0
-1.45
-2.9
Degrees
0.0
2.5
5.0
7.5
10.0
Seconds


Motor-Generator Torque
Example Case_2
1.8E+005
1.2E+005
60000.0
0.0
-60000.0
Newton-Meters
0.0
2.5
5.0
7.5
10.0
Seconds


Low-Speed Shaft Twist
Example Case_2
0.4
0.0
-0.4
-0.8
-1.2
Degrees
0.0
2.5
5.0
7.5
10.0
Seconds